APPENDIX B

ETS Emissions Calculation Methodology

Overview

ETS is a complex mixture of compounds and it would be difficult and impractical to quantify emissions based on individual compounds. We are unaware of any studies that quantify ETS emissions based on the sum of all individual compounds. Adequate analytical methods do not exist for some suspected compounds in ETS, and the cost of sampling and analysis would be high. Therefore, staff selected three compounds to characterize ETS emissions: nicotine, respirable suspended particulate (RSP), and carbon monoxide (CO). These compounds all have specific health effects associated with their exposures and have been used as markers for ETS exposures.

Nicotine emissions are unique to tobacco products and have been linked to health effects in many studies (Benowitz, 2002). Particulate matter emissions from tobacco products have been linked to respiratory problems, such as asthma, and the development or exacerbation of cardiovascular disease (Smith, 2001). Likewise, CO has also been linked to cardiovascular and birth weight effects (Horner, 2000).

Methodology

In general, staff's estimate of ETS emissions is based on emission rate studies and tobacco product sales tax data compiled by the California State Board of Equalization (BOE). For purposes of this estimate, we assumed uniform cigarette consumption among the smoking population.

Limited data exists on pipe tobacco emissions and consumption information indicates that pipe tobacco consumption is far less than cigarettes and cigars (Capehart, 2003). Therefore, staff based the ETS emission estimate predominantly on cigarette and cigar consumption. Staff's estimate of ETS emissions is based on the following equation:

$$\text{Emissions (tons/yr)} = EF \times N \times 90\% \times CF \; ; \qquad \text{(Equation 1)}$$

where: EF = Average cigarette or cigar emission factor (mg/cig)
N = Number of cigarettes or cigars per year (cig/yr)
CF = Units conversion factor (tons/mg)

Staff adjusted the number of cigarettes and cigars (by 90%) to account for the fact that smokers typically do not consume one hundred percent of a cigarette. In a study measuring mass emission rates from cigarettes, Hildemann, *et al.* (1991), found that smokers consumed approximately 90% of cigarettes and cigars.

Cigarette Emission Factors

Staff conducted a literature search to review the research on cigarette emission factors for nicotine, RSP, and CO. The literature search resulted in five studies on nicotine emission rates, six studies on RSP, and three studies on CO emission factors. The most pertinent studies are shown in the following tables. While the studies are evaluations of major national cigarette and cigar brands, the results are applicable to California since many of the brands evaluated are also marketed in the State.

Table B-1 shows the relevant studies for nicotine emission factors. From three nicotine emission factor studies, the average mass per cigarette was 1.44 milligrams (mg). One of the studies, Martin *et al*., 1997, chose the top 50 U.S. market brand styles, determined by market share, and a national average (Kentucky Research-K1R4F) cigarette. Nicotine emissions were reported for the mainstream (MS) tar content of a cigarette. The 50 top selling cigarettes represented over 65% of the U.S. cigarette market and included full flavor (FF) cigarettes (≥ 13.5 mg/cig MS tar), full flavor low tar (FFLT) cigarettes (7.5-13.4 mg/cig MS tar), and ultra low tar (ULT) cigarettes (≤ 7.4 mg/cig MS tar). The MS tar correlates to the amount of tar in mainstream smoke. The results showed a 0.1 milligram mean difference among all cigarette types.

Table B-1

Nicotine Emission Factor Studies

Study #	**Authors**	**Emission Factor**
1	Martin *et al*., 1997	1.59 mg/cig
2	Daisey *et al*., 1998	0.92 mg/cig
3	Nelson, 1994	1.8 mg/cig
Avg.		**1.44 mg/cig**

In another study, Daisey *et al*., 1998, determined the emission factors of six major cigarette brands smoked in California versus the national average cigarette (Kentucky reference cigarette -K1R4F). These six brands represented a market share of over 63% in 1990. The six brands included five filtered and one unfiltered brand; two brands were mentholated and one brand was low tar. The nicotine emission factors for all six brands showed a coefficient of variability of over 26% (.92 ± .24 mg/cig). In the study by Nelson (1994), the top 50 brands of cigarettes were analyzed for emissions generated by a person in an unventilated room.

Table B-2 shows a summary of pertinent studies on RSP emission factors. Five RSP studies result in an average mass emission rate per cigarette of 13.3 mg. Repace (2001) based his RSP emission factor on a habitual smoker model that utilizes the number of smokers per unit volume. In the same study, Repace compares two emission factors, 14 mg/cig and 10.9 mg/cig.

Table B-2

RSP Emission Factor Studies

Study #	Authors	Emission Factors
1	Repace, 2001	14 mg/cig
2	Nelson, Conrad, Kelly, 1997	14 mg/cig
3	Martin *et al*., 1997	13.7 mg/cig
4	Nelson, 1994	13.8 mg/cig
	Repace, 2001	10.9 mg/cig
Avg.		**13.3 mg/cig**

The Nelson *et al*. (1997) study generated ETS in an environmental chamber in which five replicate runs were performed while six smokers individually smoked one popular "light" cigarette. RSP yields were determined by the Martin et al., 1997, method. This method draws air at 2 liters/min with a personal sampling pump through a 1.0-µm pore membrane filter.

The Martin *et al*., 1997 study found a range of 10.5 mg/cig RSP for ULT to 14.9 mg/cig for FF, with an average of 13.7 mg/cig among the three cigarette categories. Nelson's 1994 study found an average RSP emission factor of 13.8 mg/cig.

Table B-3 shows a summary of pertinent studies on CO. Nelson *et al*.'s 1997 study determined the emission factor for CO to be 61.9 mg/cig, by a non-dispersive infrared gas analyzer, which is the same method used in the Martin *et al*., 1997, study. Likewise, Martin *et al*. found a range from 47.8 mg/cig for ULT to 57.5 mg/cig for CO for FF, with an average of 55.1 mg/cig among the three categories. The two CO emission factor studies yielded an average mass emission rate per cigarette of 58.5 mg/cig**.**

Table B-3

CO Emission Factor Studies

Study #	Authors	Emission Factors
1	Nelson, Conrad, Kelly, 1997	61.9 mg/cig
2	Martin *et al*., 1997	55.1 mg/cig
Avg.		**58.5 mg/cig**

Cigar Emission Factors

Staff conducted an extensive literature search on cigar emission factor studies for nicotine, RSP, and CO. Three different studies were found: one study involving nicotine, one study involving RSP, and two studies involving CO.

In the nicotine study from Hoffmann, 1997, premium (i.e. large) cigars were smoked under the conditions of the International Committee for Cigar Smoke Study (ICCSS). The ICCSS specifies one puff of a 20 milliliter volume, taken for a 1.5-second interval, every 40 seconds using a standardized smoking machine. The average emission factor was determined after three runs. Small cigars followed the cigarette-smoking parameters of the Federal Trade Commission, in which one puff of a 35-milliliter volume is taken for a 2-second duration, every minute using a standardized smoking machine. The nicotine emission factors for small and large cigars are 3.8 and 13.3 mg/cigar, respectively.

The Repace *et al*., 1998 study was the sole RSP emission factor study used by staff. In this study, three different experiments were conducted. The first experiment involved one Santona cigar smoked by a person in a 97 m^3 parlor of a residence for 1.3 hours. The rate of air changes per hour (ach) was 2.5. The emission factor for this cigar was 78 mg. The second experiment involved a Paul Garmirian cigar smoked by a person in a 97 m^3 parlor of a residence for 1.5 hours. The ach was 1.2. The emission factor for this cigar was 86 mg. Finally, the third emission factor was determined by a person smoking a Marsh Wheeling Stogie for 20 minutes in a 51 m^3 office. The ach for RSP was 3.8. The emission factor for this cigar was 53 mg. The overall average of these three RSP emission factors is 72 mg/cigar.

The CO emission factor was derived from two studies: Repace *et al*., (1998), and Klepeis *et al*., (1999). Over 13 different experiments were conducted between the two studies. A summary of the experimental parameters are in Table B-4.

Table B-4

Experimental Parameters for Cigar CO Emission Factors (from Repace *et al*., 1998 and Klepeis, 1999)

Cigar Brand	Machine or Person	Cigar Duration (min)	Air Exchange Per Hour	Volume of Testing Area (m^3)	Emission Factor (mg/cigar)
Santona	Person	76	2.5	97	1100
Marsh Wheeling Stogie	Person	20	3.8	51	1140
N/A	Machine	11	7.2	521	1200
N/A	Machine	11	7.2	521	1300
Sante Fe Fairmount	Machine	20	2.1	49.6	1200
Imported Ashton	Machine	28	1.8	49.6	1200
Swisher Sweets	Machine	42	0.96	49.6	980
Dutch Masters El Presidente	Machine	9	0.06	49.6	750
Antonio y Cleopatra Grenadiers	Machine	17	3.0	49.6	630
Sante Fe Fairmont	Machine	7.8	4.5	49.6	1100
Sante Fe Fairmont	Machine	24	0.12	49.6	1100
Antonio y Cleopatra Grenadiers	Machine	10	0.12	49.6	860
Antonio y Cleopatra Grenadiers	Machine	12	4.5	49.6	780

The average CO emission rate for all the experiments is approximately 1025 mg/cigar.

Number of Cigarettes and Cigars

To determine the number of cigarettes, staff relied on data from the California BOE, which maintains an annual statewide inventory of cigarette pack distributions. The BOE collects taxes at the point of distribution from certified vendors, which may conduct business across several different counties. Distribution is defined by the BOE as, “the sale or use or the placing of cigarettes in retail stock for the purpose of selling the cigarettes to consumers” (RTC, 2003). In other words, taxes are incurred at the wholesale level. To estimate emissions in California, we assumed that distribution represents actual consumption because consumers likely do not maintain large inventories.

The BOE reports that over 1.27 billion packages of cigarettes were distributed in California during the 2001-2002 fiscal year. Since the average cigarette pack contains 20 cigarettes, the total number of cigarettes distributed in California can be calculated (tot cig=20 x no. packs) to be 25.4 billion cigarettes.

In 2002, according to the Economic Research Service, United States (U.S.) Department of Agriculture, U.S. smokers consumed about 4.1 billion large cigars, gaining 10 percent from 1998, and 2.2 billion small cigars, increasing 28 percent from 1998 (ERS, 2003). However, the Economic Research Service does not compile California specific cigar inventories.

Since California represents six percent of the nationwide cigarette sales, staff estimates the number of large and small cigars in California to be 247 million (6% x 4.1 billion) and 135 million (6% x 2.2 billion), respectively.

Statewide ETS Emissions Inventory

Based on the methodology described above, staff estimated total statewide ETS emissions for nicotine, RSP, and CO. Table B-5 shows statewide emissions.

Table B-5

2002 California Statewide ETS Emissions (Tons/Year)

	Cigarettes	Cigars	Total
Nicotine	36	4	40
RSP	335	30	365
CO	1475	432	1907

Countywide emissions were also calculated using Equation 1, with the number of cigarettes being the total number of cigarettes per county (i.e. percent of total California smokers per county multiplied by the total number of cigarettes). Attachment A presents estimated emission results by county.

Emissions by Age

In addition to regional emission estimates, staff also estimated ETS emissions amongst two age groups: adults (18 years and older) and adolescents (12-17 years of age).

These two age groups comprise virtually all smokers and adults comprise about 95% of all California smokers.

For this analysis, staff used data from the Tobacco Control Section of the California Department of Health Services (DHS). Under the legislative mandate established by Proposition 99 (the Tobacco Initiative), DHS routinely conducts surveys to determine the prevalence of smoking within the California public.

Staff used the 2002 adult California Tobacco Survey (CTS) and the 2001 adolescent California Student Tobacco Survey (CSTS) smoking prevalence data shown in Attachment B. The number of smokers (adult or adolescent) per county was calculated as the 2002 population (adult or adolescent) for a given county multiplied by the established smoking prevalence (adult or adolescent) for the same county or county region, as follows:

Smokers per county = county population X county smoking prevalence

The summation of all counties indicates an estimated number of adult smokers in California of over 4.2 million, while 400,000 adolescents were estimated to be smokers in 2002.

The number of cigarettes per county is calculated by taking the number of smokers (adults and adolescents) per county as a statewide percentage, multiplying by the total number of cigarettes statewide, as follows:

Cigarettes per county = % Smokers per county X Total cigarettes statewide

A complete summary of estimated total smokers and cigarettes per California county is shown in Attachment C.

As shown in Table B-6, the total adult and adolescent cigarette emissions of nicotine, RSP, and CO in California were estimated to be approximately 36.4 tons/yr, 335 tons/yr, and 1476 tons/yr.

Table B-6

Estimated Adult and Adolescent Cigarette Emissions of Nicotine, RSP, and CO (Tons/Year)

	Adult (18+)	Adolescent (12-17)	Total
Nicotine	32.9	3.5	36.4
RSP	303	32	335
CO	1335	141	1476

REFERENCES

Benowitz N.L., Hansson A., and Jacob III P., (2002). Cardiovascular Effects of Nasal and Transdermal Nicotine and Cigarette Smoking. Hypertension. Vol. 39, pp. 1107-1118.

California Department of Health Services, (2001). The California Tobacco Control Program: A Decade of Progress, Results from the California Tobacco Survey, 1990-1999.

Capehart T. (2003). Economic Research Service, U.S. Department of Agriculture. Tobacco Outlook, TBS-254.

Daisey J.M., Mahanama K.R.R., and Hodgson A.T. (1998). Toxic Volatile Organic Compounds in Simulated Environmental Tobacco Smoke: Emission Factors for Exposure Assessment. Journal of Exposure Analysis and Environmental Epidemiology. Vol. 8, No. 3, pp. 313-334.

Economic Research Service (ERS), U.S. Department of Agriculture Website. (2003). ERS-TBS-255, Tobacco Outlook, October, 2003. http://www.ers.usda.gov/publications/so/view.asp?f=specialty/tbs-bb/

Hildemann L.M., Markowski G.R., Cass G.R. (1991). Chemical Composition of Emissions from Urban Sources of Fine Organic Aerosol. Environ. Sci. Technol. Vol. 25, pp. 744-759.

Hoffmann D. and Hoffmann I. (1997). Chemistry and Toxicology. In: Smoking and Tobacco Control Monograph No. 9, Cigars – Health Effects and Trends. National Institutes of Health, National Cancer Institute, Bethesda, MD. pp. 55-104.

Horner J.M. (2000). Anthropogenic Emissions of Carbon Monoxide. Rev Environ Health. Vol. 15(3), pp. 289-98.

Klepeis N.E., Ott W.R., Repace J.L. (1999). The Effect of Cigar Smoking on Indoor Levels of Carbon Monoxide and Particles. Journal of Exposure Analysis and Environmental Epidemiology. Vol. 9, pp. 622-639.

Martin P., Heavner D.L, Nelson P.R., Maiolo K.C., Risner C.H., Simmons P.S., Morgan W.T., Ogden M.W. (1997). Environmental Tobacco Smoke (ETS): A Market Cigarette Study. Environmental International. Vol. 23, No. 1, pp. 75-90.

Nelson P.R., Conrad F.W., and Kelly S.P. (1997). Comparison of Environmental Tobacco Smoke to Aged and Diluted Sidestream Smoke. J. Aerosol Sci. Vol. 29, Suppl. 1, pp. S281-S282.

REFERENCES (cont.)

Nelson P. (1994). Testimony of R.J. Reynolds Tobacco Company, OSHA Docket No. H-122, Indoor Air Quality, Proposed Rule. U.S. Occupational Safety & Health Administration, Washington, D.C.

Repace J. (2001). Risk Assessment of Passive Smoking: Year 2000, California. pp. 1-76.

Repace J.L., Ott W.R., Klepeis N.E. (1998). Indoor Air Pollution from Cigar Smoke. In: Smoking and Tobacco Control Monograph No. 9. Cigars – Health Effects and Trends. National Institutes of Health, National Cancer Institute, Bethesda, MD. pp. 161-179.

Revenue and Taxation Code, Section 30001-30018. Cigarette and Tobacco Products Tax Law. No. 30008.

Smith C.J. and Fischer T.H. (2001). Particulate and Vapor Phase Constituents of Cigarette Mainstream Smoke and Risk of Myocardial Infarction. Atherosclerosis. Vol. 158, pp. 257-267.

Attachment A

2002 Estimated Adult and Adolescent Cigarette ETS Emissions Per California County or County Region (lbs/year)

Region	Combined Adult & Adolescent		
	Nicotine	RSP	CO
Los Angeles	19,724	182,173	801,286
San Diego	5,677	52,433	230,628
Orange	5,394	49,817	219,119
San Bernardino	4,124	38,120	167,672
Riverside	4,116	38,012	167,194
Fresno, Madera, Merced, Stanislaus	3,978	36,204	159,246
Imperial, Inyo, Kern, Kings, Mono, Tulare	3,345	30,897	135,899
Alpine, Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer, San Joaquin, Sierra, Sutter, Tuolumne, Yuba	3,299	30,454	133,959
Alameda	2,947	27,215	119,704
Sacramento	2,871	26,519	116,645
Butte, Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Plumas, Shasta, Siskiyou, Tehama, Trinity, Yolo	2,784	25,726	113,155
Santa Clara	2,676	24,712	108,696
San Luis Obispo, Santa Barbara, Ventura	2,605	24,064	105,845
San Mateo, Solano	2,164	19,985	87,904
San Francisco	1,923	17,757	78,103
Contra Costa	1,825	16,858	74,152
Marin, Napa, Sonoma	1,739	16,061	70,645
Monterey, San Benito, Santa Cruz	1,495	13,809	60,737

Attachment B

The following table illustrates the adult and adolescent smoking prevalence within California regions in 2002. The data for these tables can be found from the County and Statewide Archive of Tobacco Statistics at http://webtecc.etr.org/cstats/ .

2002 Adult and Adolescent Smoking Prevalence by Region Within California

Region	Adult (%)
Los Angeles	16.0 (±0.8)
San Diego	15.1 (±1.2)
Orange	14.3 (±1.3)
Santa Clara	12.3 (±1.3)
San Bernardino	19.3 (±1.4)
Alameda	15.8 (±1.5)
Riverside	20.3 (±1.4)
Sacramento	17.6 (±1.4)
Contra Costa	13.7 (±1.4)
San Francisco	17.9 (±1.6)
San Mateo, Solano	14.8 (±1.4)
Marin, Napa, Sonoma	15.3 (±1.5)
Butte, Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Plumas, Shasta, Siskiyou, Tehama, Trinity, Yolo	19.5 (±1.5)
San Luis Obispo, Santa Barbara, Ventura	13.7 (±1.3)
Alpine, Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer, San Joaquin, Sierra, Sutter, Tuolumne, Yuba	17.7 (±1.4)
Monterey, San Benito, Santa Cruz	15.9 (±1.5)
Fresno, Madera, Merced, Stanislaus	19.3 (±1.4)
Imperial, Inyo, Kern, Kings, Mono, Tulare	19.9 (±1.5)

Region	Adolescent (%)
Los Angeles	14.4 (±3.9)
San Diego	18.3 (±2.9)
Orange	15.0 (±2.7)
Santa Clara	13.7 (±2.0)
San Bernardino	14.5 (±3.8)
Alameda	11.4 (±4.3)
Riverside	13.7 (±3.5)
Sacramento, San Joaquin, Stanislaus, Yolo, Yuba	16.6 (±4.3)
Contra Costa, Marin, San Francisco, San Mateo, Solano	18.9 (±4.4)
Fresno, Imperial, Kern, Kings, Madera, Mariposa, Merced, Tulare	16.8 (±3.1)
Monterey, San Benito, San Luis Obispo, Santa Barbara, Santa Cruz, Ventura.	19.2 (±4.0)
Alpine, Amador, Butte, Calaveras, Colusa, Del Norte, El Dorado, Glenn, Humboldt, Inyo, Lake, Lassen, Mendocino, Modoc, Mono, Napa, Nevada, Placer, Plumas, Shasta, Sierra, Siskiyou, Sutter, Sonoma, Tehama, Trinity, and Tuolumne.	18.6 (±5.9)

Attachment C

2002 Estimated California County Information Regarding Population, Smokers, and Cigarettes

County	Population (age 12+)	Smokers	Smoker %	Cigarettes	County	Population (age 12+)	Smokers	Smoker %	Cigarettes
Alameda	1,220,022	187,823	4.06	1,031,274,433	Orange	2,392,579	343,813	7.43	1,887,764,881
Alpine	1,054	187	0.004	1,028,072	Placer	233,056	41,468	0.90	227,685,517
Amador	32,483	5,775	0.12	31,710,818	Plumas	18,237	3,540	0.08	19,438,077
Butte	177,815	34,521	0.75	189,541,487	Riverside	1,335,738	262,339	5.67	1,440,418,884
Calaveras	37,394	6,652	0.14	36,526,234	Sacramento	1,045,404	183,024	3.95	1,004,922,459
Colusa	15,494	3,003	0.06	16,489,793	San Benito	43,083	7,006	0.15	38,467,153
Contra Costa	816,686	116,349	2.51	638,833,408	San Bernardino	1,401,270	263,089	5.68	1,444,534,034
Del Norte	23,358	4,533	0.10	24,889,929	San Diego	2,354,432	361,871	7.82	1,986,916,617
El Dorado	139,742	24,869	0.54	136,548,878	San Francisco	682,900	122,549	2.65	672,878,091
Fresno	658,381	124,995	2.70	686,304,253	San Joaquin	480,685	84,516	1.83	464,050,153
Glenn	21,489	4,166	0.09	22,871,408	San Luis Obispo	216,343	30,504	0.66	167,487,083
Humboldt	108,782	21,121	0.46	115,967,477	San Mateo	583,632	88,148	1.90	483,990,274
Imperial	117,340	22,885	0.49	125,655,482	Santa Barbara	330,086	46,684	1.01	256,328,483
Inyo	15,598	3,083	0.07	16,929,654	Santa Clara	1,374,113	170,552	3.68	936,442,457
Kern	547,837	106,898	2.31	586,941,956	Santa Cruz	211,008	34,112	0.74	187,299,820
Kings	108,712	21,263	0.46	116,747,380	Shasta	142,217	27,613	0.60	151,615,865
Lake	52,691	10,226	0.22	56,147,122	Sierra	3,040	540	0.01	2,966,634
Lassen	29,534	5,736	0.12	31,495,866	Siskiyou	37,437	7,271	0.16	39,920,666
Los Angeles	7,941,811	1,257,271	27.16	6,903,261,516	Solano	327,497	49,781	1.08	273,330,417
Madera	105,238	20,002	0.43	109,823,664	Sonoma	388,079	60,444	1.31	331,875,994
Marin	213,100	33,194	0.72	182,258,636	Stanislaus	377,308	71,734	1.55	393,868,942
Mariposa	15,054	2,652	0.06	14,561,781	Sutter	66,116	11,762	0.25	64,579,930
Mendocino	73,687	14,297	0.31	78,502,053	Tehama	46,893	9,103	0.20	49,981,545
Merced	174,831	33,136	0.72	181,936,600	Trinity	11,286	2,193	0.05	12,038,575
Modoc	7,965	1,545	0.03	8,484,977	Tulare	291,303	56,909	1.23	312,470,195
Mono	11,107	2,197	0.05	12,065,267	Tuolumne	48,386	8,596	0.19	47,195,933
Monterey	333,276	54,181	1.17	297,488,537	Ventura	625,002	88,890	1.92	488,063,220
Napa	110,232	17,209	0.37	94,488,444	Yolo	148,886	28,677	0.62	157,457,005
Nevada	82,396	14,656	0.32	80,472,160	Yuba	48,446	8,516	0.18	46,761,128